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Exhibit 1

ADVANCED TELEVISION TECHNOLOGY CENTER

An Evaluation of the FCC RF Mask for the Protection of DTV Signals from Adjacent Channel DTV Interference

Document # 97-06

July 17, 1997

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An Evaluation of the FCC RF Mask for the Protection of DTV Signals from Adjacent Channel DTV Interference

Executive Summary

The Advanced Television Technology Center (ATTC) is pleased to present the results of an evaluation of the FCC RF Mask for the protection of digital television (DTV) signals from adjacent channel DTV interference. The ATTC initiated this evaluation as part of its mission to test and recommend solutions for the delivery and reception of a terrestrial transmission system for DTV and high-definition television (HDTV). The ATTC is a private, non-profit organization supported by members of the television broadcasting and the consumer electronics industries.

The FCC, in the Sixth Report and Order, requires an RF Mask limiting out-of-band emissions from DTV stations and is intended to protect the stations on adjacent channels. However, the FCC Technical Planning Factors for adjacent channel interference are based on measured performance of the ATSC DTV system where the interfering DTV signal exhibited no out-of-band emissions.

Adjacent channel interference tests were conducted to determine if the FCC RF Mask provides sufficient protection to adjacent DTV channels. A controlled amount of nonlinearity was introduced to a DTV signal which induced out-of-band emission that closely approximated the shape of the RF Mask. The Bit Error Rate equivalent Threshold of Visibility was determined for both Upper and Lower adjacent channel interference.

The evaluation clearly demonstrates that the planning factors underestimate adjacent channel DTV into DTV interference by as much as 22 dB, because of the effects of out-of-band emission. Furthermore, the results indicate that the total power of the sideband splatter from an adjacent DTV signal is the dominant interference mechanism, rather than the in-band power.

1. Introduction

The planning factors used by the FCC for advanced television are based on test results[1] of the *digital* HDTV Grand Alliance System performed by the Advanced Television Test Center in strict accordance with the guidance of the Advisory Committee on Advanced Television Service[2]. The results were published in October, 1995. The Grand Alliance system performed better than the target specifications on all terrestrial transmission interference tests. However, effects of sideband splatter were not evaluated at that time.

All of the tests performed during the ACATS process were done in a controlled environment with linear amplification. The DTV out-of-band emission was more than 50 dB down. A practical high power DTV transmitter, however, will create intermodulation products in channels adjacent to the digital television (DTV) channel. Therefore, it was decided to repeat the adjacent channel interference tests using a DTV signal with maximum permissible out-of-band emission as defined by the RF Mask in the Sixth Report and Order[3]

Preliminary study by the Advanced Television Technology Center (ATTC) suggested that the Desired-to-Undesired ratios for Adjacent Channel interference with sideband splatter would be much greater than expected. The total average sideband power, regardless of spectral distribution, is the dominant interference mechanism rather than the in-band power of the undesired adjacent channel. The shape of the RF Mask was integrated and the average power out-of-band was found to be 39.33 dB below the total average power in-band. See appendix A for details of the integration. The sideband power exhibits random noise-like or co-channel interference-like behavior. The results of Grand Alliance tests for carrier-to-noise threshold and co-channel DTV interference into DTV were both about 15 dB. Therefore, the predicted Desired-to-Undesired ratio for Adjacent Channel interference with sideband splatter is 24 dB.

Formal tests were performed on July 7, 1997 to verify the predicted results.

2. Method

A block diagram of the test setup is provided in Figure 1. The DTV signal is split into two paths. The desired signal is delayed longer than the range of the dynamic equalizer in the receiver. The Desired DTV channel is Channel 23. The desired power levels were Moderate (-53 dBm) and Weak (-68 dBm).

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[1] Record of Test Results for *digital* HDTV Grand Alliance System from Transmission & Objective Tests, Advanced Television Test Center, (April 19 - July 21, 1995).

[2] Grand Alliance System Test Procedures - Part I: Transmission & Objective Tests, Section 3.1, FCC Advisory Committee on Advanced Television (SSWP2-1306).

[3] Sixth Report and Order, adopted April 3, 1997, FCC 97-115, (released April 21, 1997).

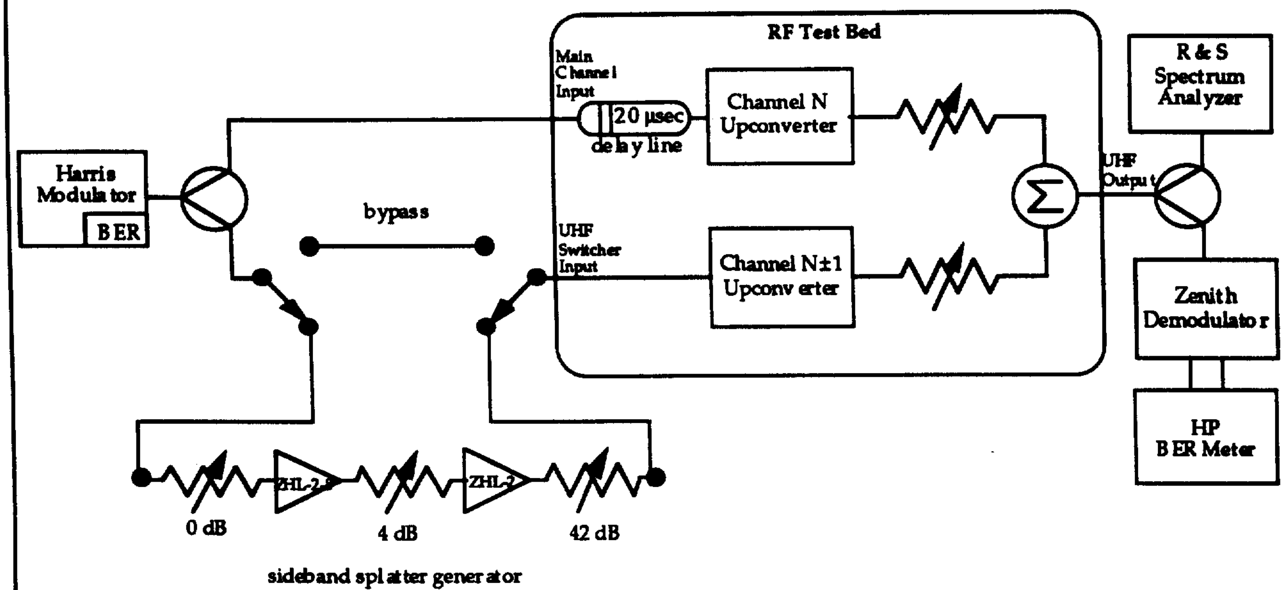

Figure 1 -- Block diagram of the ATTC test setup to measure the interference from a DTV signal into an adjacent channel DTV signal.

The Undesired DTV Signal is applied first on the Upper Adjacent Channel 24 with respect to the Desired DTV, and then on the Lower Adjacent Channel 22. The Undesired DTV signal can be subjected to controlled non-linearity in a solid state amplifier, or remain undistorted, before being up-converted to an adjacent channel. The distortion emulates sideband splatter permitted by the proposed FCC mask, - 35 dB at the DTV channel edges and decreasing away from the DTV channel. The characteristics of the out-of-band emissions are documented by the spectrum plot of Figure 2. This plot also shows the FCC Mask.

The Threshold of Visibility (TOV) is determined as follows. A Bit Error Rate (BER) meter is connected to the output of the demodulator. The undesired power is increased until the BER does not exceed 3 x 10^{-6} for three consecutive readings. Three BER readings were taken 0.25 dB above and below this level to ensure TOV had been reached. At least 20 seconds elapsed between BER readings.

The DTV signal average power was measured with a spectrum analyzer. All reported values have been corrected for a resolution bandwidth of 30 kHz.

$$P_{Avg} = 10 \cdot \log\left[\frac{6MHz}{30kHz} \cdot 10^{\frac{P_{measured}}{10}}\right]$$

$$P_{Avg} = 23dB + P_{measured}$$

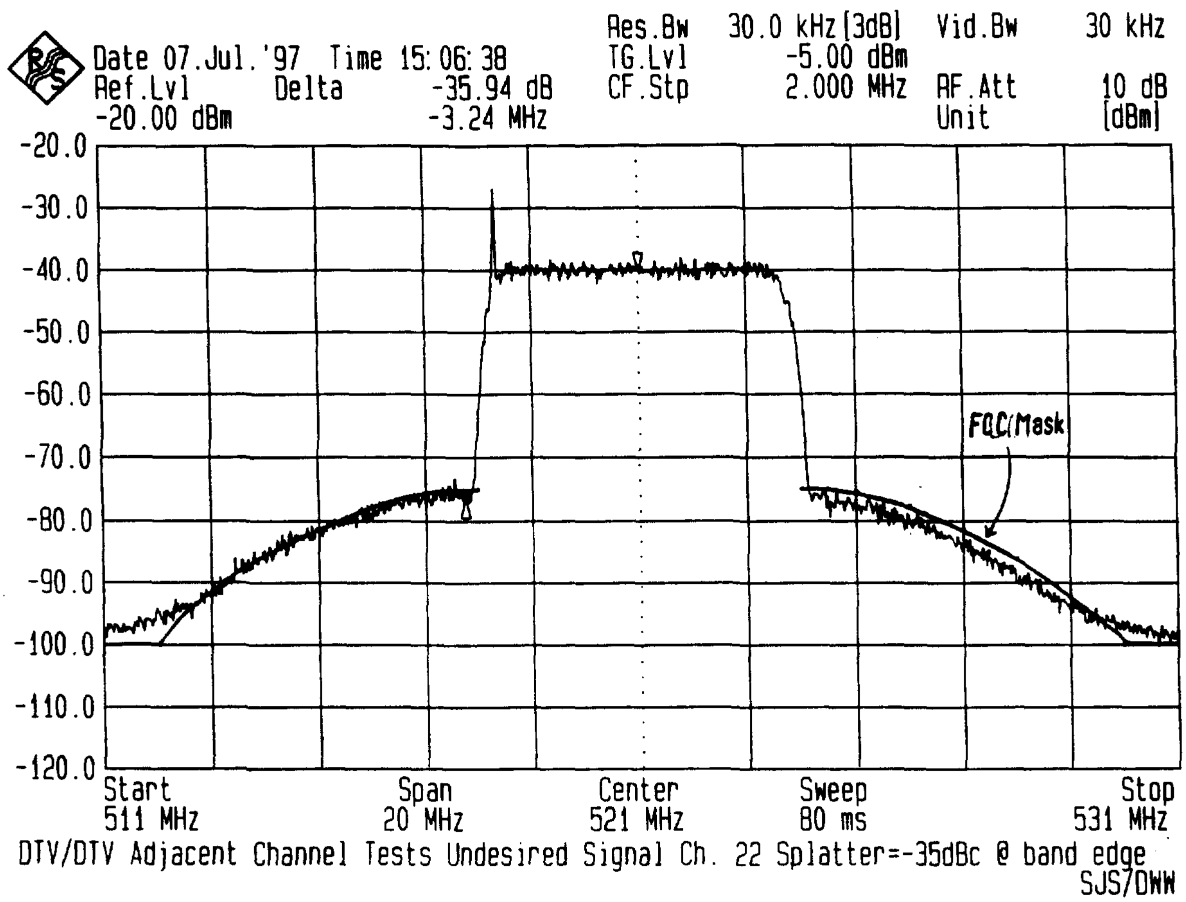

Figure 2 -- Spectrum plot showing the DTV channel out-of-band emissions which emulate the maximum sideband splatter permissible by the proposed FCC RF mask.

Note: at the frequency limits of this plot, the signal spectrum may be at the noise floor of the instrument.

3. Results

Figures 3 and 4 show the relative power levels of the Desired and Undesired signals, with sideband splatter, at TOV for the Lower and Upper Adjacent Channel interference. Interference from the DTV signal on the Lower Adjacent channel was found to have a TOV of about -23 dB Desired-to-Undesired Ratio (D/U), and interference from the DTV signal on the Upper Adjacent channel was found to have a TOV of about -21 dB D/U.

Table 1 summarizes the rest of the results of this test along with some previous results for comparison.

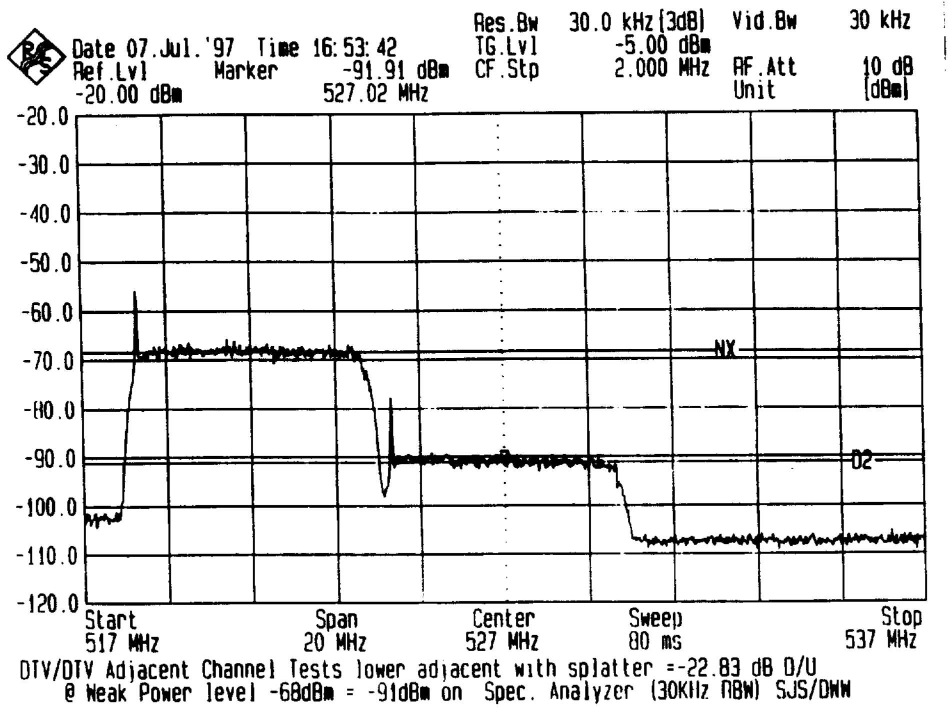

Figure 3 -- Spectrum plot of Lower Adjacent Channel Interference showing the relative power levels of the Desired and Undesired signals at TOV, where the undesired DTV signal has sideband splatter. Note evidence of sideband splatter near the left edge of the plot.

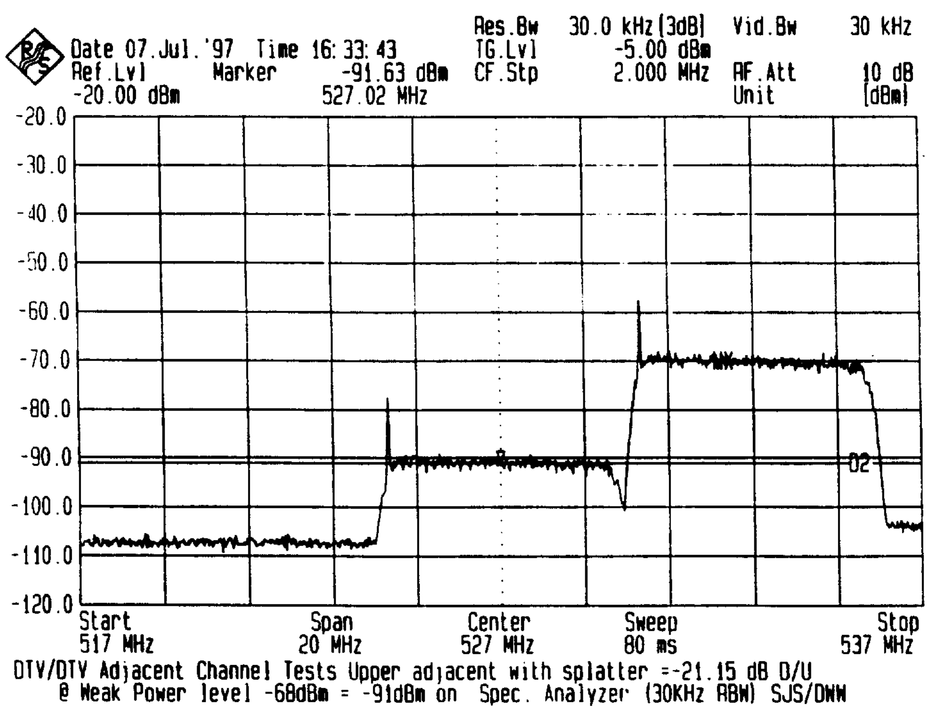

Figure 4 -- Spectrum plot of Upper Adjacent Channel Interference showing the relative power levels of the Desired and Undesired signals at TOV, where the undesired DTV signal has sideband splatter. Note evidence of sideband splatter near the right edge of the plot.

	Lower Adjacent Channel Desired Channel = N Undesired Channel = N-1 D/U (dB)	Upper Adjacent Channel Desired Channel = N Undesired Channel = N+1 D/U (dB)
Current Results		
TOV with sidebands D = -53 dBm	-23.09	-21.15
TOV with sidebands D = -68 dBm	-22.83	-21.15
TOV w/o sidebands D = -53 dBm	< -41	-37.40
TOV w/o sidebands D = -68 dBm	-41.87	-38.23
Previous Results		
FCC Planning Value	-41.98	-43.17
TOV Grand Alliance D = -53 dBm	< -38.23	-39.32
TOV Grand Alliance D = -68 dBm	-41.98	-43.17
TOV Bakeoff D = -68 dBm	-42.16	-42.86

Table 1 -- Large differences in D/U exist between a DTV signal free of IM products and one with IM products limited as per the FCC proposed RF Mask.

4. Conclusions

The adjacent channel interference threshold is much worse than the FCC planning values when legal amounts of sideband splatter are present on the adjacent DTV signal. The difference can be as high as 22 dB.

Figure 2 shows an asymmetry in the sideband splatter above and below the Undesired DTV signal. The upper sideband energy is roughly 2 dB below the FCC Mask. This is consistent with the 2 dB difference in TOV between the Upper and Lower adjacent channel cases with sideband splatter and suggests that the Lower adjacent channel TOV with sidebands should be -21 dB, not -23 dB as reported.

These results support the prediction that the total power of the sideband splatter from an adjacent DTV signal is the dominant interference mechanism, rather than the in-band power.

It is believed that the sideband splatter power from an undesired adjacent DTV signal will have a much stronger influence on the DTV reception near where the SNR approaches the threshold, e.g. 15.2 dB.

5. Acknowledgments

Many thanks to Mr. Charles Rhodes for suggesting the need for such a test based upon his integration of power under the FCC RF Mask in adjacent channels and for his valuable guidance. Thanks to Walter Husak for his confirming computer analysis of total power under the FCC RF Mask. Thanks to Mr. Dennis Wallace for his contribution to the planning and execution of this test.

Appendix

Numerical Integration of the FCC proposed RF Mask

ADVANCED TELEVISION TECHNOLOGY CENTER

Numerical Analysis of the FCC proposed RF Mask

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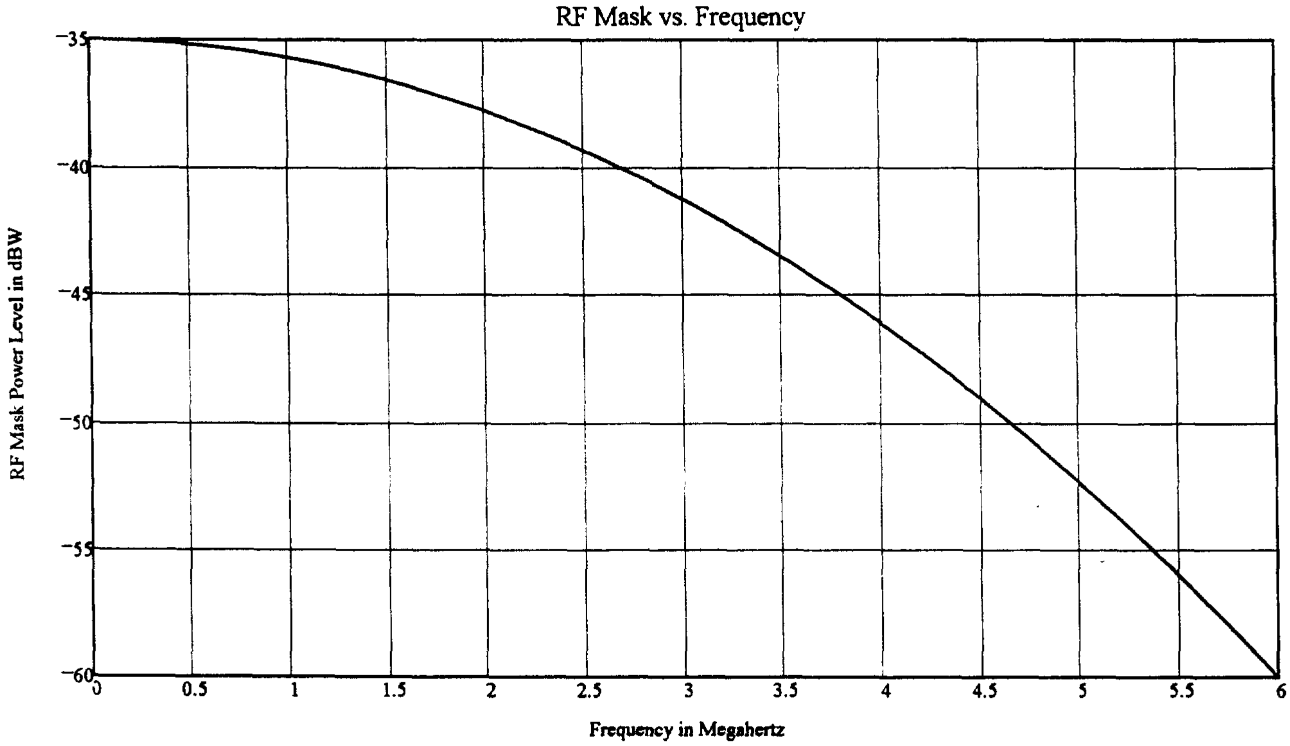
Charlie Rhodes has identified the RF Mask proposed by the FCC to be a noise-like interferor into the upper and lower adjacent channels. This paper will do a numerical analysis and symbolic integration to convert the RF Mask into an equivalent noise power figure.

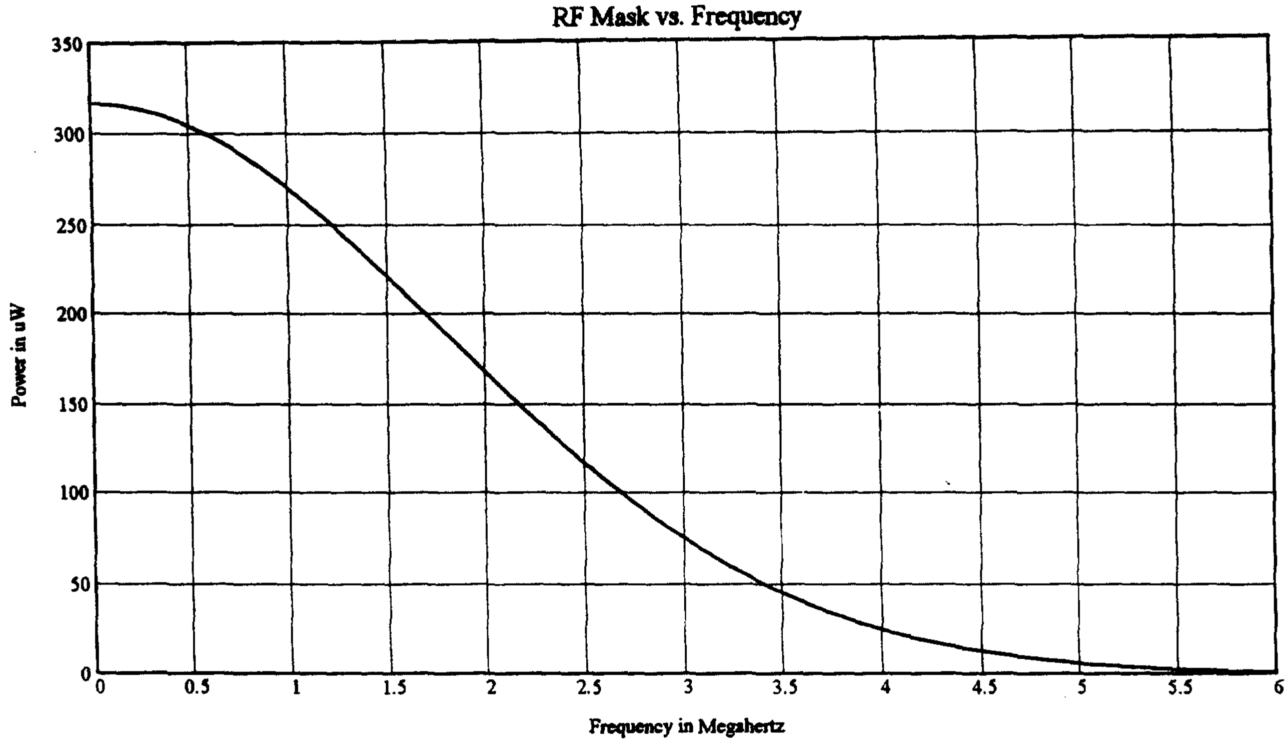
$\omega := 0, .01 .. 6 \qquad f(x) := -35 - \frac{x^2}{1.44}$



The RF Mask is described in logarithmic power levels. In order to integrate the power at each frequency point, the Mask must be redefined in absolute power terms. The following function expresses the Mask in absolute power levels relative to 1 W.

$$g(\omega) := 10^{\frac{-35-\frac{\omega^2}{1.44}}{10}}$$

Although 1 W was chosen to make the numbers easy to verify, the Mask is described by the FCC relative to mid-channel of the transmitted DTV signal. The reported equivalent noise power will be relative to the middle of the channel regardless of absolute transmitted power.



The absolute power level in the RF Mask is concentrated near the adjacent channel band edge. The mask power should contain equal power-area above and below the average power line. The numerical integration will divide the spectrum into 6000 equally sized bands. The power for each band will be calculated separately, summed together, and scaled to normalize the results.

$$i := 0..6000 \qquad X_i := 10^{\frac{f\left(\frac{i}{1000}\right)}{10}} \qquad \frac{1}{6000}\cdot\sum_{i=0}^{6000} X_i = 1.167522\cdot 10^{-4} \qquad 10\cdot\log\left(\frac{1}{6000}\cdot\sum_{i=0}^{6000} X_i\right) = -39.327$$

The variable X is a vector containing 6000 entries, each a spectral band. The sum total, scaled to the 6000 bands, is 116.75 uW. This power level translates to -39.33 dB relative to the channel center.

The next section evaluates the power as a definite integral. The non-logarithmic RF Mask equation is used as the integrand, the limit of integration is the frequency response, and the scaling factor is drawn from the intergral's limits.

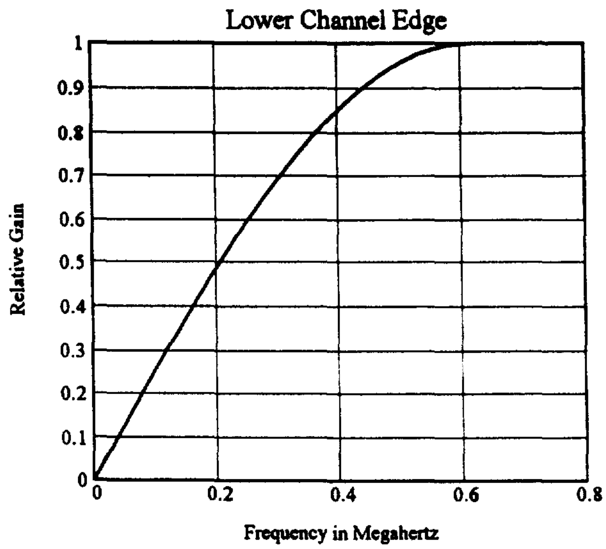
$$\frac{1}{6}\cdot\int_0^6 10^{-\left(3.5+\frac{f^2}{14.4}\right)}\,df = 1.167258\cdot 10^{-4} \qquad 10\cdot\log\left[\frac{1}{6}\cdot\int_0^6 10^{-\left(3.5+\frac{f^2}{14.4}\right)}\,df\right] = -39.328$$

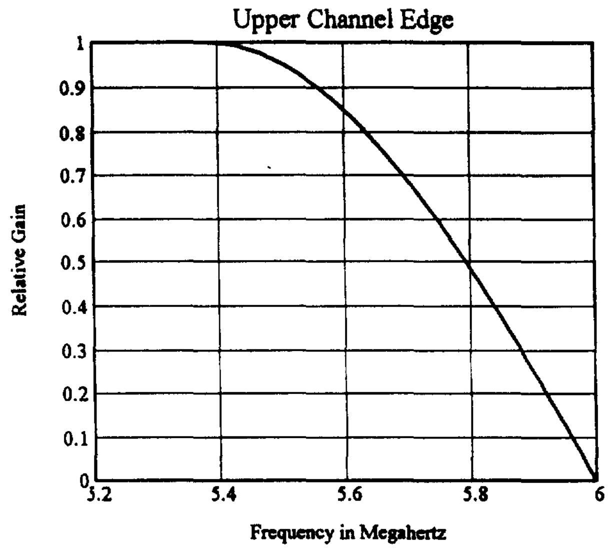
The symbolic method agrees with the numerical method. The reported equivalent noise power is -39.33 dB relative to channel center.

The interference caused by noise into the receiver is shaped by multiplying the ATSC root-raised-cosine filter with the spectra caused by the RF Mask. This next section will apply this spectrum shaping to the integrals to further refine the equivalent power measurement.

$$j := 0, .01 .. .62 \qquad l := 5.38, 5.39 .. 6$$

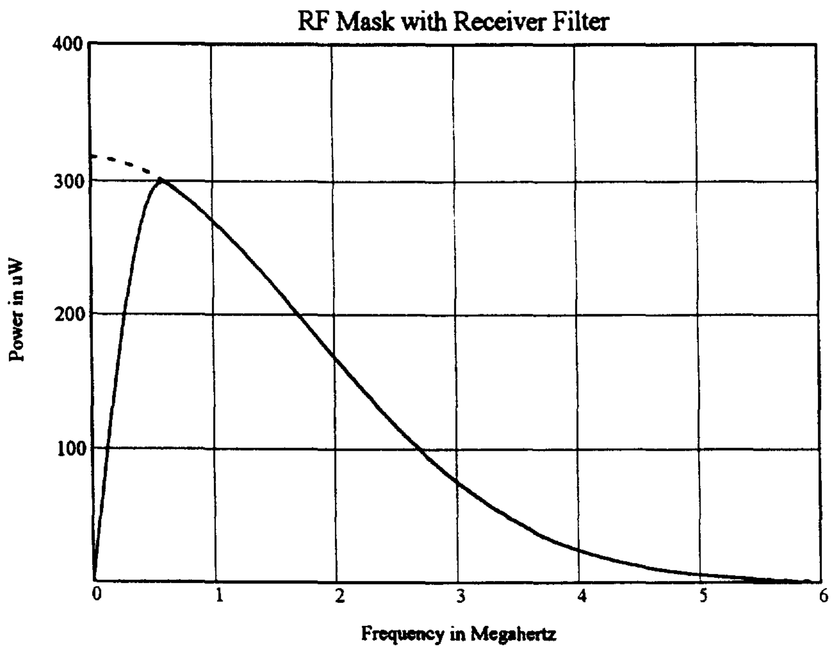
$$h(x) := \sqrt{\left(\frac{1}{2} - \frac{1}{2}\cdot\cos\left(\frac{x}{.62}\cdot\pi\right)\right)} \qquad k(x) := \sqrt{\left(\frac{1}{2} - \frac{1}{2}\cdot\cos\left(\frac{6-x}{.62}\cdot\pi\right)\right)}$$





The complexity of multiplying these functions together with the RF Mask makes piece-wise integration a natural choice. Both the numeric and symbolic integrations can be broken down into three contiguous functions. Once these sections are calculated, they can be summed together for the final result.

$$F(x) := \mathrm{if}(x<.619, h(x), 1)\cdot \mathrm{if}(x>5.379, k(x), 1)\cdot\left(10^{\frac{f(x)}{10}}\right)$$



$$Y_i := F\left(\frac{i}{1000}\right)$$

$$\frac{1}{6000}\cdot\sum_{i=0}^{6000} Y_i = 1.048766\cdot 10^{-4}$$

$$10\cdot\log\left(\frac{1}{6000}\cdot\sum_{i=0}^{6000} Y_i\right) = -39.793$$

The following three functions multiply the RF Mask with the receiver root-raised-cosine filter at each channel edge and the channel center.

$$M(x) := h(x)\cdot 10^{\frac{f(x)}{10}} \qquad \frac{1}{6000}\cdot\sum_{n=0}^{619} M\left(\frac{n}{1000}\right) = 2.02\cdot 10^{-5}$$

This is the lower channel edge.

$$I1 := \frac{1}{6}\cdot\left[\int_{0}^{.62} \sqrt{\left(\frac{1}{2}-\frac{1}{2}\cdot\cos\left(\frac{f}{.62}\cdot\pi\right)\right)}\cdot 10^{-\left(3.5+\frac{f^2}{14.4}\right)}\,df\right] \qquad I1 = 2.022\cdot 10^{-5}$$

$$N(x) := 10^{\frac{f(x)}{10}} \qquad \frac{1}{6000}\cdot\sum_{n=620}^{5379} N\left(\frac{n}{1000}\right) = 8.454\cdot 10^{-5}$$

This is the channel center.

$$I2 := \frac{1}{6}\cdot\int_{.62}^{5.38} 10^{-\left(3.5+\frac{f^2}{14.4}\right)}\,df \qquad I2 = 8.451\cdot 10^{-5}$$

$$O(x) := k(x)\cdot 10^{\frac{f(x)}{10}} \qquad \frac{1}{6000}\cdot\sum_{n=5380}^{6000} O\left(\frac{n}{1000}\right) = 1.414\cdot 10^{-7}$$

This is the upper channel edge.

$$I3 := \frac{1}{6}\cdot\int_{5.38}^{6} \sqrt{\left(\frac{1}{2}-\frac{1}{2}\cdot\cos\left(\frac{6-f}{.62}\cdot\pi\right)\right)}\cdot 10^{-\left(3.5+\frac{f^2}{14.4}\right)}\,df \qquad I3 = 1.411\cdot 10^{-7}$$

The total power is the sum of each term (I1,I2,I3). Converting back to dBW will give a relative noise power value relative to 0 dBW at the channel center. The final number is -39.8 dB below channel center. It is interesting to note the power lost in the root-raised-cosine filter is approximately 0.5 dB. In this exercise, the predominate energy is located on one side of the Mask. The total power lost in the root-raised-cosine filter will be nearer to 1 dB.

$$I1 + I2 + I3 = 1.049\cdot 10^{-4}$$

$$10\cdot\log(I1 + I2 + I3) = -39.793$$

Exhibit 2

Technical Note for Understanding DTV Service Area Maps

Note that the maps are plotted to the scale indicated in the lower right hand corner. Reference latitude and longitude, counties and some major geographical features are also plotted on the maps. The correlation between these maps and calculations performed by the FCC has been verified to be very close. The same terrain database was used. However, algorithmic differences between the Broadcasters Caucus model (adapted to the FCC methodology) and the FCC model may result in small coverage or interference differences between the two methods.

The DTV channel assigned by the FCC is used to generate these maps, using the same applicable parameter values: i.e., tower location, antenna height, antenna directional pattern as for the paired NTSC channel. Using the FCC F(50,90) curves, the noise-limited service area for the DTV channel is plotted in red.

Within this predicted noise-limited area, service losses are plotted (as radial lines every one degree and every one km along each radial) for the effects of terrain using the Longley-Rice propagation model (marked in red), interference from either other DTV stations (marked in green) or NTSC stations (marked in blue) that exceed the criteria established by the FCC for acceptable viewing. The service area that remains is the white area within the noise-limited contour.